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ENERGY ABSORPTION AND BALLISTIC IMPACT BEHAVIOUR OF KEVLAR WOVEN FABRICS

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ABSTRACT

Kevlar-29 fibers are most widely used as an impact resistance in body Armor. This study deals with energy absorption behavior, ballistic limit, of Kevlar-29 / Epoxy, Nanoclaysclosite and PaspalumScrobiculatum of different weight percentage of matrix. To investigate these behaviors in composites, the laminates are made by using Compression moulding techniques. High velocity impact testing setup consists of a piston type air gun apparatus with a projectile of diameter of 9.5 mm and 8g has been used in the laminate with the same initial velocity for obtaining the residual velocity of the target. The results revealed that the addition of Paspalum scrobiculatum promotes maximum energy absorption in the laminates produced with 5% wt of matrix.

KEYWORDS: Kevlar-29 Fibres & Compression Moulding Techniques

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Original Article

INTRODUCTION

Introduction to Bulletproof Vest

Body armor is an item or piece of clothing that is designed to protect the wearer against a variety of attacks. They can be made to stop the different types of threats, such as bullets, knives and needles, or a combination of different attacks. There are two types of body armor – soft body armor, which is used in regular bullet and stab proof vests, and hard armor, which is rigid, reinforced body armor, and is used in high risk situations by police tactical units and combat soldiers.

SOLUTION METHODOLOGY

Kevlar Reinforced with Paspalum Scorbiculatum

Kevlar reinforced with Paspalum Scorbiculatum can be the logical solution for some of the core problems. Though it cannot reduce the problem significantly, it can be able to minimize the occurrence of the problems. It will act as fillers which prevents the tensile failure of Kevlar with the matrix. The cost of natural materials is very less when compared to synthetic material. Using the natural materials can able to reduce the cost of the fabrics. It eliminates the use of synthetic material. It will also increase the energy absorption property of the material.

TARGET PREPARATION

Specimen Preparation

The Kevlar fiber cloth of 1m x 1m is cut into 8 pieces of 27cm x 27cm. The 8 pieces is divided into 4 pieces for specimen 1 and 4 pieces for specimen 2. The 4 pieces are stacked by adding a matrix to form pleats.

The two specimen plates are produced by compression molding method at 100°C. The dimension of two specimen plates is 30cm x 30cm.

Table 1: Weight of Specimen 1

	Specimen 1	
	Weight %	**Actual Weight (gm)**
Kevlar	37	148
Nano clay	3	12
Epoxy	55	220
Hardener	5	22
Paspalumscorbiculatum	0	0
Total	**100**	**402**

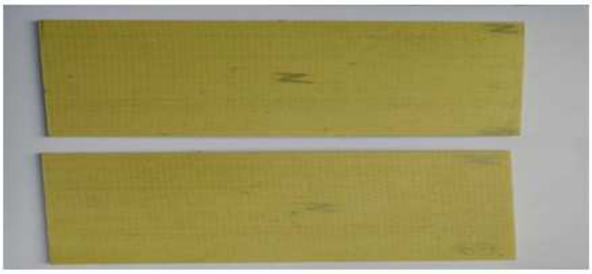

Figure 7: Specimen 1- Kevlar Reinforced with Synthetic Material

Table 2: Weight of Specimen 2

	Specimen2	
	Weight %	**Actual Weight (gm)**
Kevlar	37	148
Nanoclay	3	12
Epoxy	50	200
Hardener	5	20
PaspalumScorbiculatum	5	20
Total	**100**	**400**

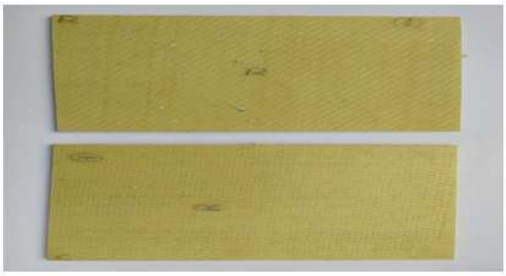

Figure 8: Specimen 2- Kevlar Reinforced with Natural Material

Each plate is cut using water jet cutting machine. Finally, each specimen containstwo plates of 15cm x 15cm of 3mm thickness.

Specification

Working temperature - 100°C

Cooling time - 30 minutes

Stages in Compression Molding Cycle

The mould should be heated. A slug or piece of the selected plastic is placed into the mould and warms up. The hydraulic press begins to travel down when the plastic has reached the right temperature. As the upper and lower mould joins, the plastic is compressed into the shape of the mould. The upper mould moves upwards and the plastic piece removed.

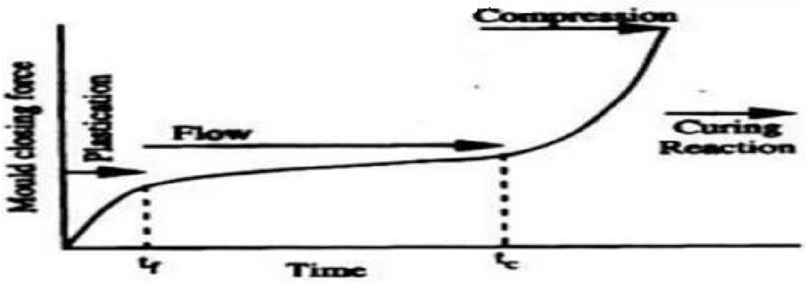

Figure 10: Stage Cycles in Compression Molding

The various stages of the compression molding cycle time can be represented as a function of the force required to close the old at a constant rate. In the plastication stage the force increase rapidly as polymer feed is compressed.

HIGH VELOCITY IMPACT TEST

Air Gun Apparatus

A gas gun or air gun suitable for ballistic testing and operable to propel a projectile at a velocity between 100 and 1000 meters per second solely by the action of a non combustible compressed gas.

Figure 11: Air Gun Apparatus

Specification of Air Gun Apparatus

Chamber Volume - 15834cc

Working pressure (chamber) - 15bar

Working pressure (pneumatic chamber) - 10bar

Maximum size of projectile – 50mm

Dimension of Bullet

Diameter - 9.8mm

Length – 16mm

Mass – 8g

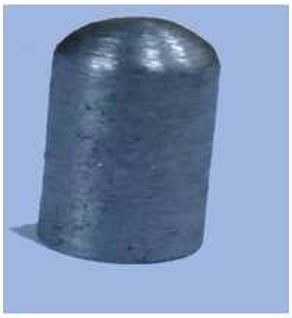

Figure 12: Mild Steel Bullet used in Firing

Ballistic Testing

Ballistic testing is a form of high speed testing that is used to test the ultimate impact strength of composites. High velocity testing is characterized by an impactor travelling in the range of 100-2000 m/s. For high velocity impact conditions, structural response is less important than in a low velocity case and the damage area is localized. Therefore, the geometric considerations are less important. Ballistics testing consists of firing a high speed projectile at an object. This is a right method for testing impact resistance of composites, and has been used for testing products such as composite armor.

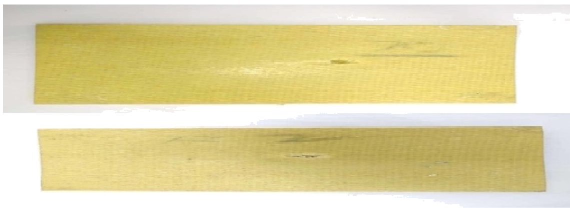

Figure 13: Target 1 after Testing

Figure 14: Target 2 after Testing

NUMERICAL ANALYSIS

Introduction to ANSYS

The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex Multiphysics analysis with drag-and-drop simplicity. With ANSYS explicit dynamics products, you get a comprehensive set of advanced tools to help gain insight into virtually any event that can be simulated. For example, the FE (Lagrange) solver is the most commonly used and the computationally fastest method to represent structures.

Simulation of Kevlar with Nano clay in Explicit Dynamics Modelling

Before Impact,

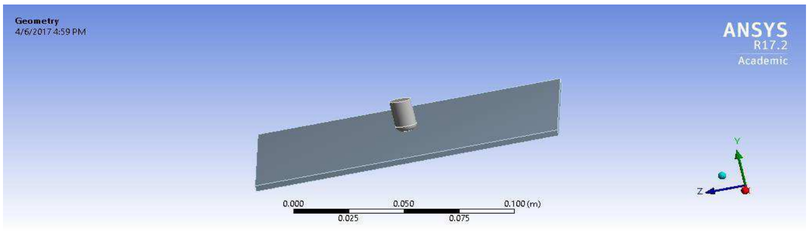

Figure 15: Kevlar with Nanoclay Model

Material Properties

In this work, we have taken composite material as orthotropic and bullet as isotropic. The properties of Kevlar with nano clay and mild steel bullet are listed below.

KEVLAR NANO13CLAY > Constants

Density	1214kg m^-3

Table 3: Properties of Kevlar Nano Clay

KEVLAR NANOCLAY > Orthotropic Elasticity								
Young's Modulus X Direction	**Young's Modulus Y Direction**	**Young's Modulus Z Direction**	**Poisson's Ratio XY**	**Poisson's Ratio YZ**	**Poisson's Ratio XZ**	**Shear Modulus XY Pa**	**Shear Modulus YZ Pa**	**Shear Modulus XZ Pa**
5.8155e+ 009	5.8183e+ 009	1.9385e+ 009	0.3	0.3	0.3	6.235e+ 009	6.1996e+ 009	2.0783e+ 009

Table 4: Properties of Mild Steel

MILD STEEL > Constants			
	Density	7850 kg m^-3	
MILD STEEL > Isotropic Elasticity			
Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
2.05e+011	0.3	1.7083e+011	7.8846e+010

RESULTS

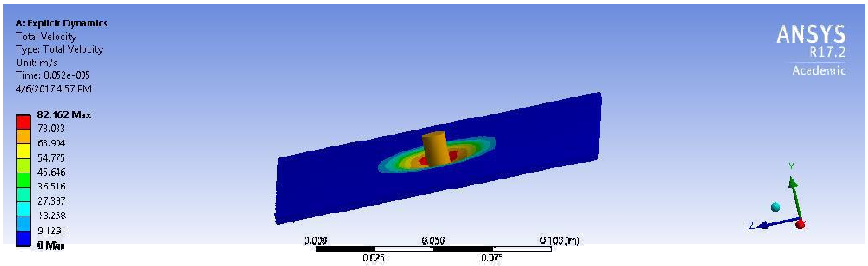

Figure 16: Total Deformation of Kevlar with Nano Clay

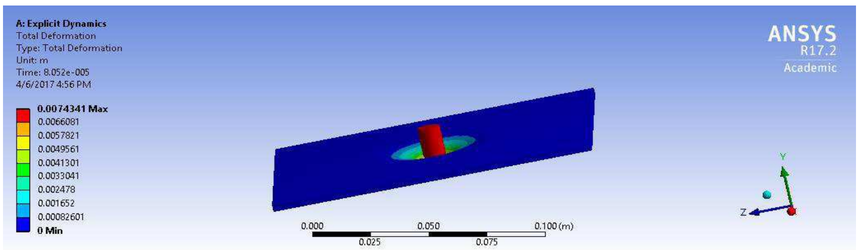

Figure 17: Total Velocity of Kevlar with Nano Clay

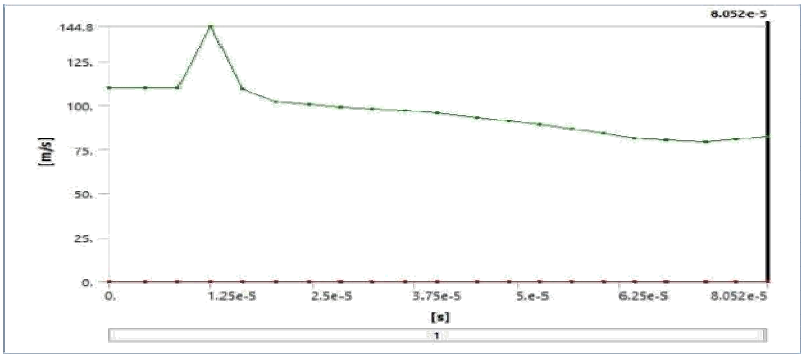

Figure 18: Deformation Graph for Kevlar with Nano Clay

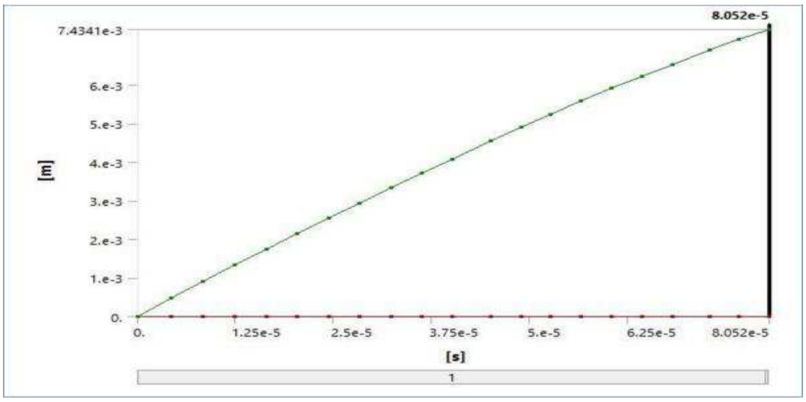

Figure 19: Velocity Graph of Kevlar with Nano Clay

Simulation of Kevlar with Nano clay and PaspalumScorbiculatum in Explicit Dynamics -Modelling

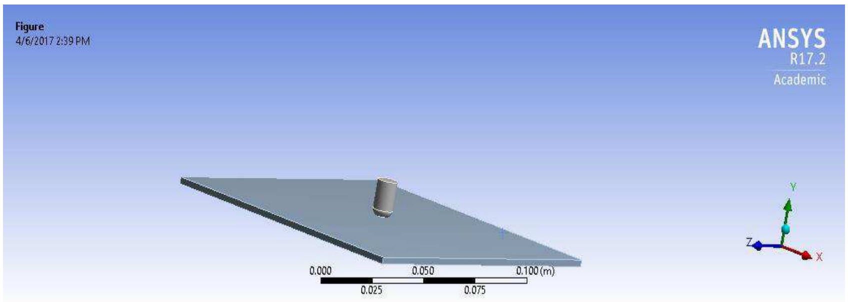

Figure 20: Kevlar with Nanoclay & PS Model

Material Properties

In this work, we have taken composite material as orthotropic and bullet as isotropic. The properties of Kevlar with nano clay and PaspalumScorbiculatum are listed below.

Table 5: Properties of Kevlar Nano clay with PS

Kevlar Rice Ash> Constants								
Density				1214 kg m^-3				
Kevlar Rice Ash> Orthotropic Elasticity								
Young's Modulus X Direction Pa	Young's Modulus Y Direction Pa	Young's Modulus Z Direction Pa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY Pa	Shear Modulus YZ Pa	Shear Modulus XZ Pa
6.0414e+ 009	5.8437e+ 009	2.0138e+ 009	0.3	0.3	0.3	7.1812e+ 009	7.9679e+ 009	2.3937e+ 009

The material used for bullet is mild steel. The properties of mild steel bullet are listed below:
MILD STEEL > Constants

Table 6: Properties of Mild Steel

Density		7850 kg m^-3	
MILD STEEL > Isotropic Elasticity			
Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
2.05e+011	0.3	1.7083e+011	7.8846e+010

RESULT

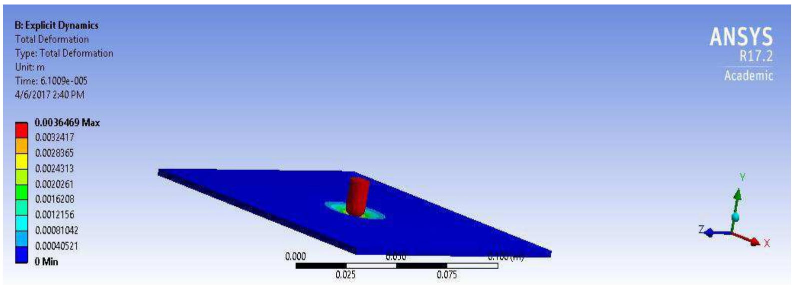

Figure 25: Total Deformation of Kevlar with Nano Clay & PS

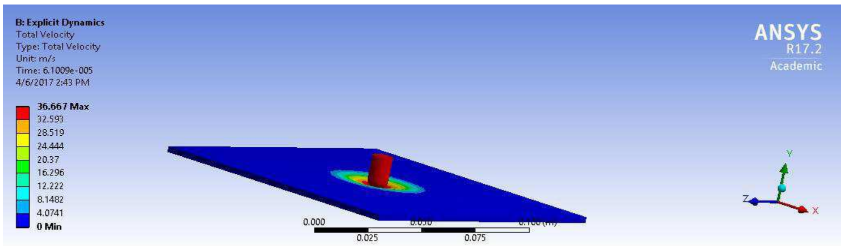

Figure 26: Total Velocity of Kevlar with Nano Clay & PS

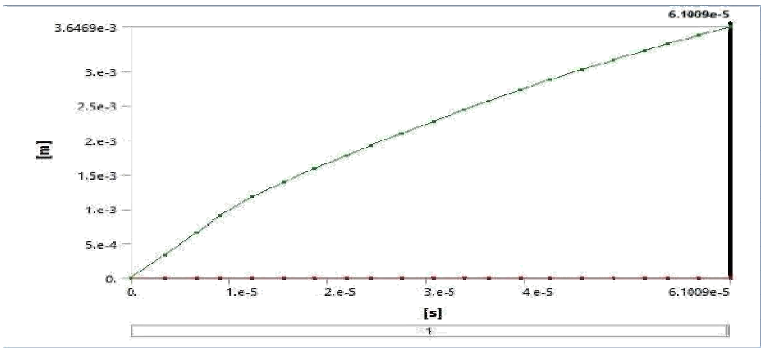

Figure 27: Deformation Graph for Kevlar with Nano Clay & PS

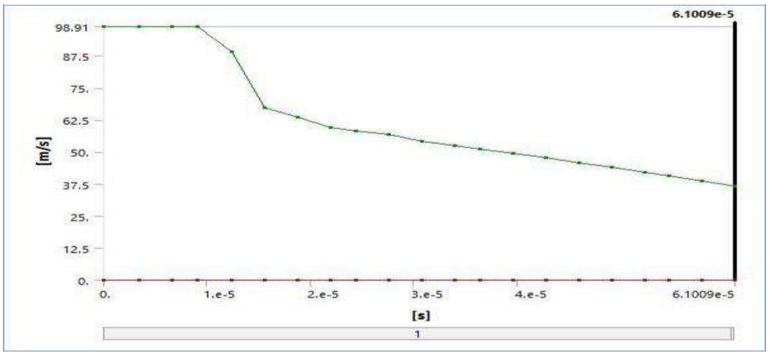

Figure 28: Velocity Graph for Kevlar with Nano Clay & PS

RESULTS AND DISCUSSIONS

Experimental Results

These are the experimental results for the two plates of target 2- Kevlar reinforced with paspalumscorbiculatum and one plate of specimen 1- Kevlar reinforced with Nano clay.

Table7: Residual Velocity of the Targets

S. No	Target	Location no of Projectile	Initial Velocity	Residual Velocity	Observation after Penetration
1	Kevlar riceash 1	1	91.25	13.12	Projectile found with higher degree of rotation
2	Kevlar riceash 1	2	88.36	20.54	
3	Kevlar riceash 1	3	94.16	18.23	
Average		**91.25**	**17.29**		
1	Kevlar riceash 2	1	95.75	37	Straight line projectile path
2	Kevlar riceash 2	2	102.12	39	
3	Kevlar riceash 2	3	98.88	39	
Average		**98.91**	**38.3**		
1	Kevlar nanoclay	1	108.75	76.0412	Straight line projectile path
2	Kevlar nanoclay	2	111.714	76.215	
3	Kevlar nanoclay	3	107.401	76.854	
Average		**109.28**	**76.3160**		

The formula for energy absorption is

Energy absorption = ½ $m(V_I – V_R)^2$

Where,

V_I= Initial velocity

$V_{R=}$ Residual velocity

M= weight of bullet = 8g

Table 8: Energy Absorption of Targets

Target	Weight Percentage of Paspalum Scorbiculatum (%)	Initial Velocity (m/s)	Residual Velocity (m/s)	Energy Absorption (J)
Kevlar with 0% ps	0	109.28	76.32	4.345
Kevlar with 5% PS	5	91.25	17.29	21.88

From the results, we observe that the addition of PaspalumScorbiculatum will increase the energy absorption of

the material. By adding 5% of PaspalumScorbiculatum, energy absorption will increase by 80%.

Comparison of Experimental Results with Numerical Results

The following are the results of experiments and numerical analysis

Table 9: Comparison of Experimental and Numerical Results

Target	Residual velocity (m/s)		Error %
	Experimental Results	Numerical Results	
Kevlar with Nano clay	76.31	82.16	7.12
Kevlar with Nano clay & PS	38.3	36.67	4.26
		Average error % =	5.69

The experimental results were compared with the results obtained in the Explicit dynamics in ANSYS workbench. The error for two targets are 7.12% and 4.26%. The average error was found to be 5.69%.

CONCLUSIONS

Ballistic impact response and Energy absorption behavior of laminated composites with nanoclays and paspalumscrobiculatum was studied by different weight percentages of paspalumscrobiculatum. The test results were compared with the kevlar laminates filled with nanoclays only. The results revealed that the addition of paspalumscrobiculatum significantly increases the energy absorption in the laminates. For the initial velocity of 140 m/s the maximum energy absorption increases by about 80% for the laminates with 5% of PS the same was determined by using ANSYS Explicit Dynamics and the results were compared and found in good agreement with the experimental results.

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